Athens Institute for Education and Research
ATINER

ATINER's Conference Paper Series
EDU2018-2622

The Flipped Classroom:
Effects on Students Performance in Mathematics

Diana Audi
Senior Instructor
American University of Sharjah
UAE

An Introduction to ATINER's Conference Paper Series

Conference papers are research/policy papers written and presented by academics at one of ATINER's academic events. ATINER's association started to publish this conference paper series in 2012. All published conference papers go through an initial peer review aiming at disseminating and improving the ideas expressed in each work. Authors welcome comments

Dr. Gregory T. Papanikos
President
Athens Institute for Education and Research

This paper should be cited as follows:

Audi, M. (2018). **"The Flipped Classroom: Effects on Students Performance in Mathematics",** Athens: ATINER'S Conference Paper Series, No: **EDU2018-2622.**

Athens Institute for Education and Research
8 Valaoritou Street, Kolonaki, 10671 Athens, Greece
Tel: + 30 210 3634210 Fax: + 30 210 3634209 Email: info@atiner.gr URL: www.atiner.gr
URL Conference Papers Series: www.atiner.gr/papers.htm
Printed in Athens, Greece by the Athens Institute for Education and Research.
ISSN: 2241-2891
04/03/2019

The Flipped Classroom: Effects on Students Performance in Mathematics

Diana Audi
Senior Instructor
American University of Sharjah
UAE

Abstract

The introduction of advanced multimedia technologies in higher education have resulted in mixed responses both from the students and teachers. The flipped classroom is a pedagogical teaching technique that was introduced during the last five years. Flipped Classrooms make use of pre-planned video lectures for students to watch and practice at home while group-based in depth problem solving activities are conducted in class with the supervision of the class teacher allowing for more focused individualized learning in class. Previous research studies investigate student perceptions regarding flipped classrooms without investigating the effect of such teaching methodologies on student performance in more technical subjects including Mathematics. Combining several learning theories including active, in-class problem-based learning activities and instructional video lectures, this research paper presents an in-depth analysis of the flipped classroom in teaching Mathematics at the American University of Sharjah, a leading American based Curriculum University in the United Arab Emirates. Using statistical analysis, the results of this study show that there is an evident improvement on student performance using flipped classrooms compared to traditional techniques.

Keywords: Flipped Classrooms, Mathematics, Student Performance, Student Perception, Technology in Education

Introduction

Using advanced technologies in higher education teaching have witnessed great improvements over the last ten years. Multimedia tools including online interactive courses and virtual classrooms have represented a major part of higher education enrollments. Use of Augmented and Virtual reality tools as well as cloud computing to compliment in-class discussions have also changed the way students engage with lecture notes both inside and outside the classroom [23]. Also, more advanced technology including shared surfaces for students in classrooms and dynamic lectures notes were studied in [24] More notable, the concept of flipped classrooms has emerged in recent years that use an inverse methodology where students watch video lecture notes prepared by the course instructor and come to class to apply the concepts presented in the class lecture notes. This allows the teacher to focus on specific applications of concepts and not waste time on static lecture notes.

Research on video lectures in general has supported the hypothesis that video lectures outperform normal delivery marginally [1]. Adding interactivity features to the video lectures results in better performance and efficiency [2,3]. Giving students home assignments using technology has also shown promising results compared to normal handwritten assignments as shown in the works of [4,5]. ITS (intelligent tutoring systems) have also been an interesting research area with results showing they have the potential to replace normal tutors [6]. Although there is a clear wave for the use of video lectures in current education systems, real implementations have been a been slower than expected due to many reasons including the commitment of the academic institution including financial and providing proper support and facilities for teachers to record and deliver interactive video lectures.

With respect to online courses and video lectures leading universities around the world have taken significant actions to provide education for all using video lectures technology including MIT’s OpenCourseWare (OCW) and Khan academy. Other efforts inspired by such initiatives include Udacity and Coursera which hosts a multitude number of online video repository for higher education courses and EdX which is a collaboration between top universities to offer free open course video lectures [7].

In terms of mathematics and engineering education which is the subject of this research paper, university learning objectives linked with international and national accreditations demand specific outcomes as per course syllabus including the ability to solve mathematical problems, and the ability communicate and work in teams. Such restrictions make the delivery of basic video lectures or even interactive ones not viable in mathematics subjects especially introductory mathematics subjects. Some proposed solutions include the use of Problem-based learning methods [8] which help in achieving such learning objectives and corresponding outcomes. However, the syllabus of Mathematics subjects is already quite packed giving little room for maneuver and would not allow the application problem based methodologies in class as that would potentially lead to less content delivered and not achieving the course learning objectives. These facts among others lead to the introduction of flipped classrooms variations where students are assigned home readings and video lectures to watch and analyze prior to attending physical lectures. This will allow teachers to have more time to focus on specific problems in class including Q&A about the video lectures first followed by solving sessions. We represent a basic view of the flipped classroom used in this research paper in Fig. 1.

Figure 1. *Major attributes of the flipped classroom model*

Related Work

The earliest works on flipped classrooms include the work of [9] where they defined what a flipped classroom is. In simple terms, they refer to a flipped classroom as a technique that inverts the whole learning experience where events that usually take place inside the classroom would be taken outside the classroom and vice versa. Their interpretation is obviously incomplete as it implies a simple shifting of the activities without taking into consideration the pedagogical inferences in such shifting. In reality, such a definition would not suffice [9,10]. Most research works on the flipped classroom employ group-based interactive learning activities inside the classroom based on well known learning theories [11]. There have also been a number of theoretical frameworks on flipped classrooms over the years including [12] where the authors discuss peer assisted learning tools along with guidelines for teachers to implement such methodologies. Collaboration and cooperation techniques adapted from [11] were the basis of their theoretical framework.

Utilizing flipped classrooms have a direct correlation with student learning styles which confirm that every student learn differently. More specifically, taking into consideration every student's skills and interest combined with teaching methodologies will have a direct impact on the efficiency of the teaching tools used. Published research in this area include the works of [13]. Several dimensions including perception, processing and understanding based on Psychology were identified including different permutations leading to different learning styles. As cooperative learning is an essential part of the flipped classroom methodology, there has been a number of research works [14] that combined learning theories to identify factors necessary for cooperative delivery. Active learning has also been discussed in the literature indicating the need to engage students using home and class activities [15]. It is also clear that active learning and problem based learning are interrelated.

Combining problem based learning methodologies with cooperative learning and active learning resulted in a number of research analysis on the use of flipped classrooms including the works of [16,17]. Although different academics used different delivery methods for the flipped classrooms, most studies focused on the perceptions of students engaged is such deliveries. The results were very positive in most cases indicating that students were very excited to watch the video lectures prior to the classroom physical lectures even when they were not explicitly assigned [18] which contradicts with research indicating that university students don't usually complete reading assignments at home [19]. Students also indicated that they enjoyed problem solving sessions in class compared to normal lectures and preferred shorter videos to watch at home. Other works included [20] which utilized narrated home presentations in Biology and computer interaction courses. In both works, multiple sections of the same course, with same syllabus were conducted simultaneously using flipped and normal classroom deliveries showing promising results for the flipped classroom methodologies.

More recently, there have been a number of interesting research on the use of flipped classrooms on several disciplines in higher education include the works of [21,22]. General analysis on the benefits of flipped classrooms was discussed in most works while more specific high school experiments with flipped classrooms were discussed in [21]. Higher education flipped classrooms analysis on specified subjects including nursing and medical related disciplines were discussed in [22]. In a more related discipline to our study, engineering education was combined with flipped classrooms. The authors presented a wide range of approaches from published work on flipped learning in engineering education and provided guidance for practitioners who are planning to apply such methodologies.

To summarize, most work on flipped classrooms have focused more on student perceptions and tied them to existing theories with limited works analyzing the effects of such deliveries on student performance in general and more specifically on mathematics university level subjects. This research paper focuses on such an objectives and attempts to analyses the effects and implications on the usage of flipped classrooms on a mathematics related subject at the American University of Sharjah, UAE.

Research Methodology

In order to analyze the effectiveness of the flipped classroom, this research did a comparative analysis between multiple sections of the same mathematics subject delivered by same instructors using both normal delivery and flipped methodologies over one semester at the American University of Sharjah. More specifically, the results shown in this research paper focus on the performance of the students in the first midterm exam during Spring 2018. Also, a quantitative analysis using a survey was conducted in each of the sections utilizing flipped classrooms to get more on student perception towards such deliveries. The subject under study was Math 001 which is a preparatory Mathematics subject for Engineers which emphasizes the basic skills and techniques of algebra and trigonometry. The subject also explores real and complex numbers, basic arithmetic, equations and inequalities, study of functions, polynomial and rational functions, exponential and logarithmic function, trigonometric functions and limits. Most students are Freshman level with very few at the sophomore level. Each session of the normal class

In the flipped classroom settings, the videos and the interactive pdf notes for the previous semester were posted on the universities learning management system (iLearn) allowing students to do prior preparations before class time. Four sections of the same course were used in this study with around 100 students in total. Two sections (with around 50 students) were used as a control group with normal subject delivery while the other two sections (with around 44 students) were taught using flipped classroom methodologies. More specifically, the flipped classroom methodology employed included the following:

1. The instructor asked the students to prepare the narrated notes and video lectures before they came to class and they would expect to be quizzed on the concepts at the start of the class before working in-depth on problem solving.
2. Students were asked to download poll everywhere application on their smart phones in order to be used for in-class assessment of homework readings.
3. The class instructor prepared a number of critical multiple choice questions related to homework assignments to be used to know what to focus on during the problem solving sessions in class.
4. The instructor encouraged the students to prepare the narrated notes and video lectures before they came to the class. However, unfortunately not all students did so. A preliminary survey indicated that only 70% of the students prepared the narrated notes before the class, with the other 30% failing to do so even when it was explicitly assigned to them.
5. At the start of each flipped classroom session, a quick poll was done to verify who was able to understand the concepts on their own before the problem solving sessions. Several concerns were raised regarding content based on the different students learning styles. The general consensus is they had a good understanding of the basic concepts but specific details were ambiguous to many.

The class time was carefully designed as follows based on the preliminary survey conducted:

- *20-25 minutes*: The first part of each session was used to go over the narrated lecture notes again in class giving brief explanation on the main concepts of the required section including some important rules that should be learned.
- *20-25 minutes*: The students were asked to go to the poll everywhere application and to solve the assigned problems. During that time, the teacher went to the students who were finding difficulty to solve the problems, trying to help them and re-explain the difficult concepts for them. Also, some of the students understood the concepts and the ways of solving, but they got stuck in the calculation and the algebraical simplifications at the end of the problems (examples include: how to solve a radical equation, or add fractions), therefore the instructor gave them some hints to continue the problem.

Every session had about six problems to be solved in class based on the home narrated lectures. The problems were carefully designed to include the major concepts and common mistakes students might face in that section. Once the results of each question was polled and collected wirelessly, the instructor focused on the majority of the wrong answers explaining what pitfalls students might have fallen into. The use of the flipped classroom gave more room to do individualized peer evaluation and cooperative learning during class hours.

The students from the four sections were assessed in Exam 1 which included multiple concepts on: Lines, solving inequalities, functions, domain, range, compositions of functions, symmetry, and transformation. The flipped classroom was used for about one whole month prior to conducting the exam assessments. Also, a survey was conducted after the exams to evaluate student perceptions regarding the flipped class room experience. The normal classroom setting for the same subject would serve as baseline to assed flipped classroom efficiency. In a normal setting, lessons were designed with normal classroom events such as lecture, activities, and other educational techniques. For homework, students were given practice exercises about the material covered in class to be done at home. Using both performance evaluations and students perceptions, our research framework is summarized in Fig.2

Figure 2. *Research Framework Attributes*

Results and Analysis

In this section, we will discuss results from the two different experiments we conducted. Our first objective was to study the positive effects of flipped classroom on student exam performance in Mathematics Engineering Subject. The results from Exam1 which was identical across all sections were used to test our hypothesis. Our second objective was to collect student perceptions regarding such technologies and techniques and how it affected their performance and understanding in their opinion.

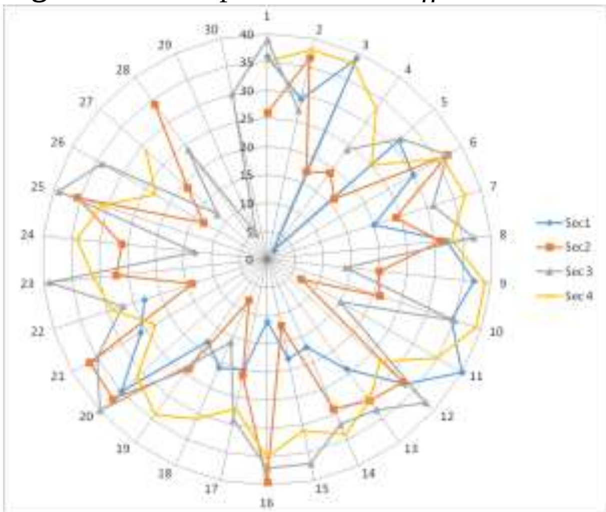
Improved Performance

For this analysis, we make the following null and alternative hypothesis:

H_0: *The usage of Flipped Classrooms does not student subject performance*
H_1: *The usage of Flipped Classrooms improves student subject performance*.

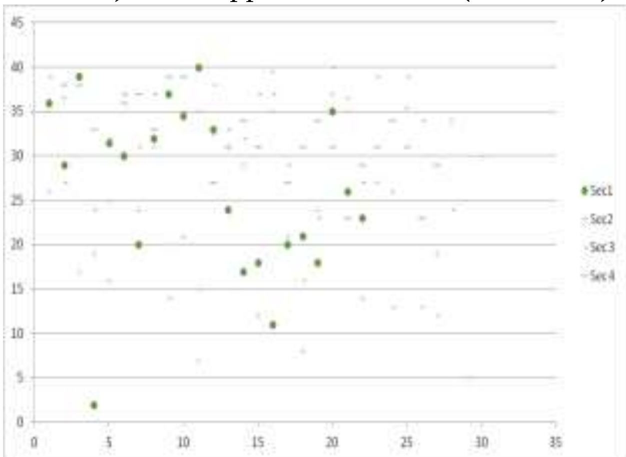
Fig. 3 show a radar plot for all four sections with regards to student exam 1 performance (marked over 40). Sec1 and Sec2 were the control groups with traditional lecturing while Sec3 and Sec4 were the experimental groups with flipped classrooms. It is evident from the plot which shows student results with respect to a central point for all four sections that the outer layers are mostly from sec3 and sec4 showing that those sections outperformed the other sections in most results.

Figure 3. *Radar plot with the Different Values of Student Performance in Exam1*



Also, a scatter plot shows the variation of the student results across all four sections as shown in Figure 4. With the vertical axis representing the grades of the student over 40, it can be noted that sec3 and sec4 dominate the upper half of the plot and hence outperform the other sections.

Figure 4. *Scatter plot Of Student Results in Exam1 Over 40 Of both Traditional (Sec1/Sec2) And Flipped Classrooms (Sec3/Sec4)*



More specifically, the descriptive statistics for all four sections in Exam1 is presented in Table 1.

Table 1. *Exam 1 Results Descriptive Statistics*

	Sec 1	*Sec 2*	*Sec 3*	*Sec 4*
Sample Size	22	28	29	11
Average /40	26.2273	24.76786	28.75862	29.36364
Average %	66%	62%	72%	73%
Stdev	9.75501	9.478516	9.814913	9.091455

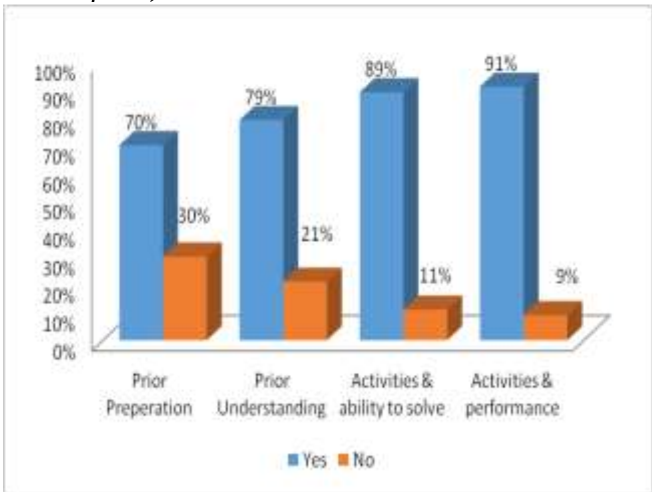
To test the hypothesis, a pooled variance two sample t-test was used with confidence interval of 95%. The p-value was less about 0.007 indicating that we have sufficient evident to reject the null hypothesis and conclude that the usage of flipped classrooms positively influences student performance in Engineering Mathematics.

Student Perception

Another major objective of this research was to collect and analyze student perception regarding flipped classrooms. More specifically, we focused on the effect of flipped classrooms on students understanding of the material and prior preparation. We also looked at the activities conducted in class after the students have prepared at home including the usage of the wireless polling systems to assess their understanding combined with lectures.

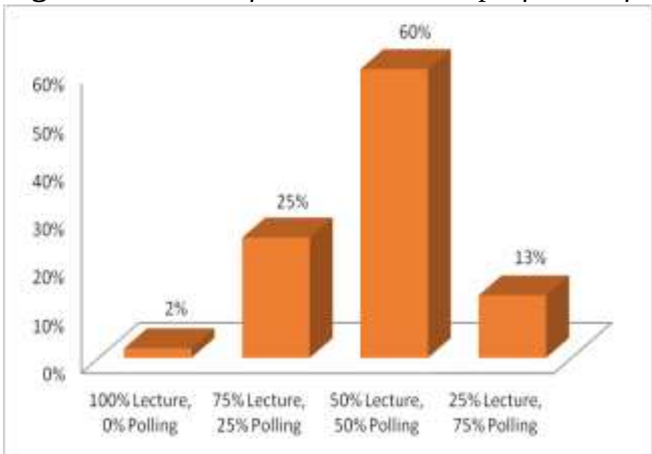
A summary of the results is shown in Figure 5. It can be noted that students perceive flipped classrooms as very positive in terms of its effect on the prior understanding and preparation for the class with 79% and 70% positive responses respectively. With regards to in-class activities, students also agreed that the use of wireless voting systems effect bother their understanding of the material and their ability to solve more problems with 91% and 89% positive responses shown.

Figure 5. *Student Perception on the Use of Flipped Classrooms both At Home (Prior Preparation/Prior Understanding) and In Class (Ability To Solve / Ability To Perform)*



Another measurement we were interested in was to see the distribution of the classroom delivery between assessing students understanding using clickers and delivering summary lectures on the material prepared from home. The results are shown in Fig 6. It can be noted that about 60% of the students preferred an equal mix between lecture reviews and wireless clickers assessments.

Figure 6. *Students feedback on their preference for in-class delivery*



Conclusions

In this research, we provide an in-depth analysis on the use of flipped classrooms in teaching engineering mathematics subjects that the American University of Sharjah, UAE. The difference between student grades in Exam1, significant survey results, and student's comments on the benefits of the flipped classroom warrants further interest and research in its use in the engineering mathematics education. We used both inferential and descriptive statistics to support evidence for our claims. We believe that the future of education lies not on the availability of technology but on how we would use innovative technology to improve students' performance and provide an individualized learning environment for every student based on their special interests. Future studies should discuss how flipped classrooms can be combined with other technologies including telepresence or augmented realities to improve the whole learning experience.

References

1. P.A. Cohen, B.J. Ebeling, and J.A. Kulik. A meta-analysis of outcome studies of visual-based instruction. Educational Technology Research and Development, 29(1):26–36, 1981.
2. D. Zhang, L. Zhou, R.O. Briggs, and J.F. Nunamaker. Instructional video in e-learning: Assessing the impact of interactive video on learning effectiveness. Information & Management, 43(1):15–27, 2006.

3. Barbara J. McNeil. A Meta-analysis of interactive video instruction: A 10 year review of achievement effects. PhD thesis, University of Idaho, 1989.
4. S.W. Bonham, D.L. Deardorff, and R.J. Beichner. Comparison of student performance using web and paperbased homework in college-level physics. Journal of Research in Science Teaching, 40(10):1050–1071, 2003.
5. H. Fynewever. A comparison of the effectiveness of web-based and paper-based homework for general chemistry. The Chemical Educator, 13(4):264–269, 2008.
6. Kurt VanLehn. The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. Educational Psychologist, 46(4):197–221, 2011.
7. edX, 2012. URL http://www.edxonline.org/release.html.
8. R.M. Felder and R. Brent. Designing and teaching courses to satisfy the ABET engineering criteria. Journal of Engineering Education, 92(1):7–25, 2003. ISSN 1069-4730.
9. M.J. Lage, G.J. Platt, and M. Treglia. Inverting the classroom: A gateway to creating an inclusive learning environment. The Journal of Economic Education, 31(1):30–43, 2000.
10. J. Foertsch, G. Moses, J. Strikwerda, and M. Litzkow. Reversing the lecture/homework paradigm using eteachR web-based streaming video software. Journal of Engeneering Education-Washington, 91(3):267– 274, 2002.
11. L.S. Vygotsky. Mind and society: The development of higher mental processes. Cambridge, MA: Harvard University Press, 1978.
12. H. Foot and C. Howe. The psychoeducational basis of peer-assisted learning. In K.J. Topping and S.W. Ehly, editors, Peer-Assisted Learning, pages 27–43. Lawrence Erlbaum Associates, 1998.
13. David A. Kolb. Experiential learning: Experience as the source of learning and development, volume 1. Prentice-Hall Englewood Cliffs, NJ, 1984. ISBN 9780132952613. URL http://books.google.com/books?id=ufnuAAAAMAAJ.
14. P.E. Doolittle. Understanding cooperative learning through Vygotsky. In Lily National Conference on Excellence in College Teaching, Colombia, SC, June 2-4 1995.
15. M. Prince. Does active learning work? A review of the research. Jounal of Engeneering Education-Washington, 93:223–232, 2004.
16. C. Papadopoulos, A. Santiago-Román, and G. Portela. Work in progress: Developing and implementing an inverted classroom for engineering statics. In Frontiers in Education Conference (FIE), 2010 IEEE, 2010.
17. C. Papdopoulos and A. Santiago-Román. Implementing an inverted classroom model in engineering statics: Initial results. In Proceedings of the ASEE Annual Conference & Exposition, Louisville, Kentucky, 2010.
18. Janet L. DeGrazia, John L. Falconer, Garret Nicodemus, and Will Medlin. Incorporating screencasts into chemical engineering courses. In Proceedings of the ASEE Annual Conference & Exposition, 2012.
19. J. Sappington, K. Kinsey, and K. Munsayac. Two studies of reading compliance among college students. Teaching of Psychology, 29(4):272–274, 2002.
20. J. A. Day and J. D. Foley. Evaluating a web lecture intervention in a human–computer interaction course. IEEE Transactions on Education, 49(4):420–431, 2006.
21. Lo, C.K.; Hew, K.F. A critical review of flipped classroom challenges in K-12 education: Possible solutions and recommendations for future research. RPTEL 2017, 12.

22. Karabulut-Ilgu, A.; Jaramillo Cherrez, N.; Jahren, C.T. A systematic review of research on the flipped learning method in engineering education. BJET 2017.
23. MK Watfa, DM Audi, New learning methodologies using modern technologies, International Journal of Innovation and Learning, 17 (3), 275-297, 2015
24. M Watfa, Cloud computing and E-learning: Potential pitfalls and benefits, proceedings of the Sixth International Conference on Innovative Computing Technology (INTECH), pages: 140-144, 2016